MULTIJUNCTION THERMAL CONVERTERS

BY COMMERCIAL CMOS FABRICATION

Michael Gaitan, John Suehle
Semiconductor Electron. Div.
Natl. Inst. of Stds. and Tech.‡
Gaithersburg, MD 20899

Joseph R. Kinard
Electricity Div.
Natl. Inst. of Stds. and Tech.‡
Gaithersburg, MD 20899

D. X. Huang*
Ballantine Laboratories, Inc.
Cedar Knolls, NJ 07927

Abstract

New multijunction thermal converters fabricated in a commercial CMOS foundry are described and the results of measurements of their ac-dc transfer characteristics are given.

Introduction

New multijunction thermal converters (MJTCs) have been fabricated as microstructures in a commercial CMOS IC foundry such as offered by MOSIS† [1]. These new MJTCs are suitable for the measurement of ac voltage or current for frequencies ranging from audio to above 1 MHz using conventional thermal transfer techniques. The main innovation of this work is the ability to manufacture the device in such a commercial process. This allows easy integration with VLSI microcircuits using standard design libraries and leads to low-cost, foundry-independent products.

Fabrication

It has been demonstrated that three dimensional microstructures can be realized in a routine, commercial CMOS process with an additional post-processing etch procedure [2,3]. This step is a "maskless" etch in ethylene diamine-pyrocatecol-water carried out after devices are received from the foundry. Special layout considerations and methods are used to create an open area that exposes the silicon surface to the etchant [4] producing suspended structures composed of layers of metal and polysilicon encapsulated in SiO_2.

Thermal converters have recently been constructed using custom processing [5]. These devices used additional layers of SiO_2-Si_3N_4-SiO_2 to create suspended membranes by backside etching of Si and special metallization layers for the thermocouples. In our work, only the "standard" layers that are available in a routine commercial CMOS process are used. A similar approach was also demonstrated in [6]; however, a Si_3N_4 layer was used in those structures which is not generally available at commercial CMOS foundries.

Figure 1 shows a picture of a typical device fabricated through the MOSIS service. The MJTC is a cantilever structure with a suspended, resistance heating element and thermocouple hot junctions located near the heater on the cantilever. The pit etched below is 150x150 μm in size. The heater structure is composed of a polysilicon resistor and the thermocouples are made of aluminum-polysilicon. These thermocouples have been shown to have a significant Seebeck effect [6].

Results

Typical overall sensitivities of about 15 mV/mW have been measured in air. Some structures have been made with thermal time constants of 3 ms; however, other designs made with greater thermal mass have longer time constants. Approximate ac-dc differences of the new MJTCs, measured as voltage converters at 1 V, are -10 ppm at 10 kHz, -210 ppm at 100 kHz, and -260 ppm at 1 MHz. The dc reversal errors are generally a few tens of ppm.

These results indicate that these low-cost, foundry-fabricated MJTCs are very promising as RMS sensors for use in general instrumentation up to and beyond 1 MHz.

This work was supported in part by the Calibration Coordination Group of the U.S. Dept. of Defense and by the Navy Advanced Test Equipment and Metrology Program at NRAD in San Diego, Calif. ‡U.S. Department of Commerce, Technology Administration. *Currently working as Research Associate in the Electricity Division, NIST. †Certain trade names are mentioned in the text in order to adequately specify the procedure and equipment used. In no case does such identification imply recommendation or endorsement by NIST, nor does it imply that the products are necessarily the best available for the purpose.

0-7803-1229-5/93/$3.00 © 1993 IEEE

References

[1] MOSIS is an acronym for MOS Implementation System. The MOSIS service is located at the University of Southern California's Information Sciences Institute, Marina del Ray, Calif.

[2] M. Parameswaran, H. P. Baltes, Lj. Ristic, A. C. Dhaded, and A. M. Robinson, "A New Approach for the Fabrication of Micro-mechanical Structures," *Sensors and Actuators*, vol. 19, pp. 289-307, 1989.

[3] M. Parameswaran, A. M. Robinson, D. L. Blackburn, M. Gaitan, and J. Geist, "Micro-machined Thermal Radiation Emitter from a Commercial CMOS Process," *IEEE Elect. Device Letters*, vol. 12, no. 2, pp. 57-59, Feb. 1991.

[4] M. Parameswaran, R. Chug, M. Gaitan, R. B. Johnson, and M. Syrzycki, "Commercial CMOS-Fabricated Integrated Dynamic Thermal Scene Simulator," *IEDM Digest*, pp. 753-756, Dec. 1991.

[5] J.R. Kinard, D.X. Huang, and D.B. Novotny, "Multilayer Thin-film Thermal Converters," *CPEM '92 Digest*, pp. 56-57, 1992.

[6] H. Baltes, D. Moser, T. Boltshauser, R. Lenggenhager, O. Brand and D. Jaeggi, "Microtransducers by CMOS and Micromachining," *Proc. of the 4th Int. Symposium of ASIC and Transducer Technology*, Belgium, pp. 71-87, 1991.

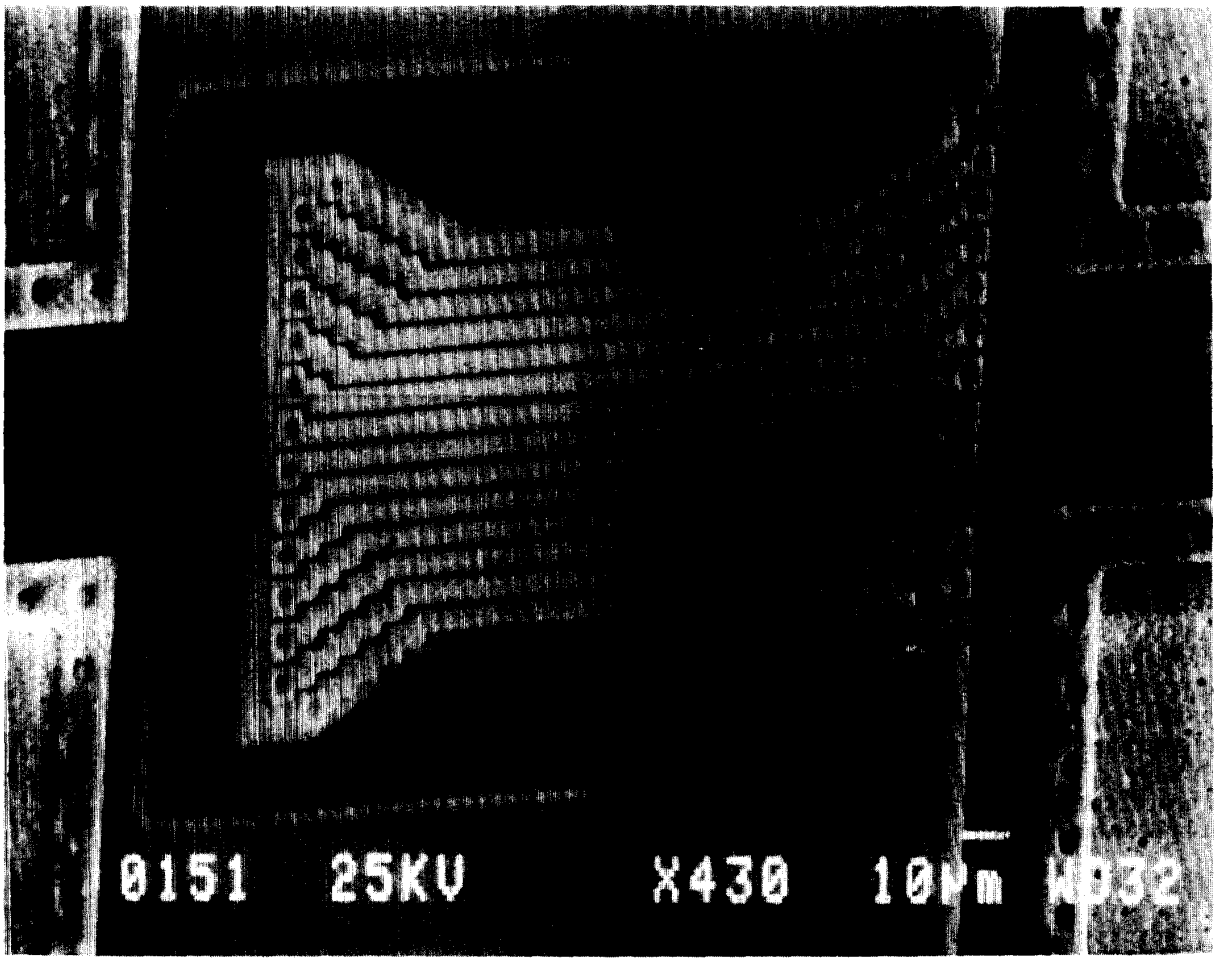

Fig. 1. An SEM micrograph of a multijunction thermal converter fabricated in a commercial CMOS process.